Comments on ANGEO manuscript 2021-501
By Ellis Remsberg

We would like to thank the reviewer for taking the time to assess our manuscript. We will address all of the reviewer's comments in the following paragraphs.

I have several concerns and suggestions for the manuscript version under review, and I have already passed them along to the authors privately. Their reply to me indicates that accounting for anomalous HALOE profiles makes a quantitative difference for their findings, but does not change their conclusion that there may be some effect on temperature in late 1991 from the Pinatubo eruption. However, I do not think that the Pinatubo effects extend to 1993. The following paragraphs give my comments on the version of the manuscript that is currently under review. I am sure that the authors will make appropriate revisions based on their updated findings.

We would like to thank the reviewer for drawing our attention to the HALOE measurements that are tagged as unreliable because of problematic trip and/or lockdown angles. We revised our analysis and inserted a short sentence in the 'data and data analysis' section of the manuscript from line 78-79: "Measurements that were tagged as being problematic due their corresponding trip or lockdown angle (http://haloe.gats-inc.com/user_docs/index.php) were dismissed from the analysis."

My past work on analyzing HALOE temperatures was exploratory, initially, because I was looking also for the Pinatubo effect that was alluded to by She et al. (1998). I was concerned about decadal-scale, dynamical influences, so I decided not to regress against a solar flux proxy, but to fit temperature series with an 11-yr sinusoid and check about its phasing with that of a solar cycle proxy. Subsequent to Remsberg and Deaver (2005), I discovered that I had not accounted properly for autoregressive effects. I reported on that realization and then updated my analyses in Remsberg (2007). I also used that revised approach in the analyses of Remsberg (2008; 2009). Most recently, I reported on analyses of HALOE water vapor in the mesosphere, and I included further updates about HALOE temperature, as well (Remsberg et al., 2018). For that study, I included a regression term for a solar proxy (Lyman-alpha flux) and a dynamical term related to an ENSO proxy (MEI index), and I obtained a good fit to the H2O time series and an improved fit to the temperature time series. However, I did not include a volcanic aerosol proxy term because I did not see that one was indicated from the time series of the model/data residuals.

We thank the reviewer for his comment on the necessity of a volcanic proxy to fit the HALOE temperature data. Our analysis hints to unusually high temperatures at the beginning of the time series only in some altitude/latitude segments of the mesosphere. These are the focus of this manuscript and seem to suggest a warming that might be related to the prior eruption of Mt. Pinatubo. We are nevertheless aware that no direct correlation between the Pinatubo eruption and a warming of the mesosphere was proven by our study, but that it might add a small contribution to the ongoing discussion in the community.

After reading your manuscript, I re-analyzed HALOE temperature time series at 0.03 hPa in the manner of Remsberg et al. (2018), see Figure 1 below. In that paper I noted that there are so-called 'trip angle' biases in many of the SR profiles of November 1991 and April 1992; that problem is described in more detail on the GATS, Inc., HALOE Website homepage, including which profiles are not trustworthy. The regression analysis for Fig. 1 begins in October 1991 and includes SR and SS profiles at 37N +/- 7.5 degrees of latitude, which overlaps the sodium lidar station at Fort Collins (41N); you can compare them with that of Remsberg and Deaver (2005, Fig. 6). The response in Fig. 1 of HALOE T(p) to the Lyman- alpha flux proxy (max-min) is +1.8 K, and the analyzed linear trend for T(p) is -2.4 K/decade.

We again thank the reviewer for bringing our attention to the existence of the trip and lockdown angle problem. We revised the data analysis (see answer given above).

Figure 2 is my analysis for T(p) at 0.01 hPa or nearer to the sodium layer viewed by She et al. The response of T(p) to Lyman-alpha flux is +3.3 K, but the linear trend is now weakly positive (+0.46 K/decade) although it is not significant. In addition, my analyzed coefficient for the ENSO index is 0.86 K/MEI index, and it is highly significant. This pressure altitude of 0.01 hPa is where the dissipation of gravity waves (and the phase of ENSO) may be affecting temperature. Again, my regression model fits the data well, even during the year or so following the Pinatubo eruption.

Finally, Figure 3 is an "image" of the longitude/pressure cross section for SS profiles on 15 December 1991 at 38N latitude. Note that HALOE viewed this latitude only about once every month or so. You may access and view similar images at the HALOE Website by clicking on 'Browse images' on the left menu of the homepage, and then selecting from the next pop-up page, a longitude/pressure plot, the parameter of interest (temperature), the months of a given year, and whether you wish to look at SS and/or SR scans. When you make your request at the bottom of that Webpage, the list of days that you asked for appears along with their mean latitude; clicking on one particular day then allows you to view more images. I show Fig. 3, so that you will see that there was a region of warm temperatures (225 K) near 0.01 hPa and about 270 E longitude (~Ft. Collins). There is also a pronounced zonal wave-1 in T(p) at this pressure level (see the cold values of ~200K near 60E). To my mind, this longitudinal variation in T(p) indicates effects from the interaction of planetary waves with gravity waves in the upper mesosphere. It may be that there is an indirect connection with the Pinatubo event, too, wherein its aerosol layers have altered slightly the meridional T(p) gradient of the lower stratosphere and allowed for a redirection of the transmission of gravity waves to the mesosphere. On the other hand, transport times and radiative relaxation rates are short in the upper mesosphere, such that any temperature anomalies decay quickly. A sustained transmission of gravity waves would be necessary to maintain those anomalies, in my opinion.

We would like to thank the reviewer for taking the time to provide the plots that he shared. Our study so far considered zonal mean temperatures. We included a new figure (Figure 7 in the revised version) where we present the results of our two fitting approaches for measurement data sampled between 60°-120°W. This region includes the location of the lidar station in Fort Collins. The plots with the limited longitude range supports the overall argument of our paper and we added it together with a short description to the manuscript, beginning from line 173: "This conclusion is still valid when only the longitudes between 120°W to 60 °W are considered that include the position of the lidar station at Ford Collins (41°N, 105°W). The left side of Figure 7 shows the temperature anomalies according to an episodic perturbation similar to Figure 3, but for the restricted longitude range. Positive amplitudes above 40°N are detected from 60 – 75 km and even up to 80 km above 20 – 30°N. The amplitude above 80 km in the northern hemisphere is still negative. Using the exponential decay function (right side of Figure 7) suggests positive amplitudes in most of the upper mesosphere in the northern hemisphere with a maximum positive temperature at 40°N above 80 km of approximately 5 K."

Additional references:

Remsberg, E. E., A re-analysis for the seasonal and longer-period cycles and the trends in middle atmosphere temperature from HALOE, J. Geophys. Res.—Atmospheres, vol. 112, D09118, doi:10.1029/2006JD007489, 2007.

Remsberg, E. E., On the response of Halogen Occultation Experiment (HALOE) stratospheric ozone and temperature to the 11-yr solar cycle forcing, J. Geophys. Res.-Atmospheres, 113, D22304, doi:10.1029/2008JD010189, 2008.

Remsberg, E., Damadeo, R., Natarajan, M., and Bhatt, P.: Observed responses of mesospheric water vapor to solar cycle and dynamical forcings, J. Geophys. Res., 123, 3830-3843, https://doi.org/10.1002/2017JD028029, 2018

We would like to thank the referee again for taking the time to review our manuscript and for providing additional graphics that added value to the ongoing discussion of volcanic-driven signals in the middle atmosphere in the community.